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The Agronomic Value of the Sewage Sludge of Tenerife. Physico-Chemical Characteristics of the Refuse–Sludge Compost and Related Products

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ABSTRACT

This paper evaluates the most important agronomic characteristics of the sewage sludge from the Tenerife wastewater treatment plant and the compost obtained by composting of this sludge with the organic fraction of municipal refuse. A comparative study is also carried out on several commercial products used as organic dressings on the island's agricultural soils.

From the results obtained, the direct use (after sterilization) of sewage sludge could be very interesting from the agricultural point of view. The compost obtained, because of its high total (43·6%) and oxidisable (37·3%) organic matter content, its high fertilizer elements concentration (N, 2·8%; P, 1·3%; K, 1·6%; Ca, 5·2% and Mg, 1·1%), its balanced essential elements content and moderate toxic heavy metals levels, can be considered a good organic fertilizer whose use could represent a great saving in chemical fertilizers and replace the manures formerly used, which are now almost non-existent. In addition, it could compete advantageously with the products at present on sale in the island because of its lower cost and better agronomic quality.

INTRODUCTION

The application of organic matter to agricultural land in the island of Tenerife has decreased considerably in recent years as a result of the almost total disappearance of traditional sources of organic dressings—animal manure and forest residue. One of the most effective means of

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offsetting this organic matter deficit is the recycling, for agricultural use, of sludge from the wastewater treatment plants, either direct after stabilization and sterilization processes or by means of composting, mixed with the organic fraction of domestic refuse.

At present, the wastewater treatment plant in Tenerife generates a large quantity of sewage sludge which could raise serious environmental problems in the future since the plant follows the classical means of elimination (dumping, incineration) and has not, until now, recycled any of the sludge for agricultural purposes. The use of sewage sludge in agriculture has been widely practised in the most developed countries. It is estimated that 30% of the total sludge production in EEC countries is recycled for agricultural use; up to 70–80% being used in Switzerland (Juste & Catroux, 1980).

It is obvious from the extensive literature on the subject that sewage sludge, applied directly to agricultural land or composted with domestic refuse, is an important source of organic material and essential nutrients for plant growth (Juste, 1979; Diez, 1981; Catroux, 1982). Because of its high organic matter content it can cause great modifications in certain physico-chemical and biological characteristics of the soil and lead to an improvement in its fertility (Epstein, *et al.*, 1976; Morel & Jacquin, 1980; Furrer & Stauffer, 1981) and prove, additionally, a valuable source of N and P—the main reason for the beneficial effects observed in plants (Sabey & Hart, 1975; Magdoff & Amadon, 1980; Hall, 1983).

The principal limitation in the agricultural use of sewage sludge is potential phytotoxicity because of the high heavy metals content which it sometimes shows (Andersson, 1977; Cottenié, 1981; Chaney, 1983).

The aim of the present study was the evaluation of the most important agronomic characteristics of the sewage sludge from the Tenerife wastewater treatment plant and the compost obtained by means of composting it with the organic fraction of municipal refuse. A comparative study was also carried out on several commercial products used as organic dressings on agricultural land in Tenerife.

METHODS

The sludge used in this study was from an activated sludge plant, dried in drying beds. When dehydrated, five samples of the sludge were taken in the uppermost layer (5 cm), in different areas of the drying beds, for analysis.

In addition, 375 kg of this sludge (17·80 moisture) were mixed with the organic fraction of domestic refuse (856 kg and 44·11% moisture) and the mixture was composted by a process similar to that used by Kehren (1967) as has been previously described (Iglesias Jiménez *et al.*, 1986).

The analysis of the compost (Tenerife compost A) was compared with those of six products on sale in the island, of which four are called 'organic fertilizers or dressings' (C, D, E and F) and the other two, 'organic-mineral fertilizers to correct deficiencies' (G and H). For comparison the composition of a compost made in the traditional manner, on a banana plantation in the north of the island (Orotava compost B), is also shown. The Orotava compost is made with vegetable residues, banana plant, forest residues and weeds. These materials are put into layers, forming a windrow of 1·5 m wide and 1·5 m high, and supplied with enough water to maintain the moisture at a suitable level.

All the samples (sludge, compost and commercial products) were dried in the open air, ground in a 1 mm mesh hammer mill and analytical determinations were made as before (Iglesias Jiménez *et al.*, 1986) with Volatile Solids being determined with the ash.

RESULTS AND DISCUSSION

Sewage sludge

Table 1 shows the analysis of the sludge from the sewage station. This sludge shows an acidity close to neutral (pH 6·9) and a relatively low EC (2·5 mmhos cm^{-1}) so that its direct use in agriculture, in moderate amounts, would not, in principle, imply the risk of salinization of the soil. Moreover, high levels of total and oxidizable organic matter (50·7% and 43·1%, respectively) are seen, which are within the limits (33–55% organic matter) most often quoted in the literature (Sommers, 1977).

Similarly, the high N values (4·4%) found are near the normal concentrations which vary from 2% to 5% (Juste & Catroux, 1980), although the greater part of this N is in organic form since it is activated sludge. The total phosphorus content is of the order of 0·9%, not a

TABLE 1
Physico-chemical Analysis of the Sludge Utilized in Composting of Domestic Refuse–Sewage Sludge. (Average of Five Repetitions)

Per cent moisture	17·8		
pH (extr. 1:5)	6·9		
EC (mmhos cm^{-1})	2·5		
	Per cent (dry matter)		
Volatile Solids	51·1	C/N	6·7
Ash	48·9		
Total C	29·4	Total P	0·9
Total organic matter	50·7	Total K	0·5
Oxid. C	25·0	Total Ca	2·4
Oxid. organic matter	43·1	Total Mg	1·1
Total N	4·4		
	ppm (dry matter)		
Fe	30 720	Pb	217
Cu	134	Co	21
Mn	599	Ni	298
Zn	537	Cd	5

high value when compared with those found in the literature (0·1–14·3%; average value, 2·5%). Of this total, P, 51·1% is in the available form (Iglesias Jiménez, *et al.*, 1986). The P is explained, on the one hand, by the relative richness of this element in domestic waste water (excrement, detergents, etc.), and, on the other, by the fixation phase present in the sludge (polyvalent metals and their hydroxides) (Juste & Catroux, 1980). The K level found in this sludge is 0·5%, a low value fairly frequent in this type of residue; thus, Sommers (1977) gives an average content of 0·4%. Almost all the K is in inorganic form, so that K, although low, is easily assimilated by the plants, its availability being similar to that of mineral potassic fertilizers (Sabey & Hart, 1975).

The calcium levels vary around 2·4%, a value which, although relatively high, does not reach the content most often quoted in the literature (4·9%). For Mg, the concentration obtained is 1·1%, higher than the values most often noted for this type of product (0·54%; Sommers, 1977). Thus, the sludge can be used as an efficacious magnesic fertilizer.

The levels of essential and toxic microelements do not exceed the maximum concentrations laid down in different European countries for the direct use of sewage sludge in agriculture (Table 2), with the

TABLE 2
Proposed Limits in European Countries for Heavy Metals in Sewage Sludge for Agricultural Use (mg kg^{-1} Dry Weight)
(Data from: Purves (1981): Switzerland and Scotland; Commission of the European Communities (1982))

	Elements					
	Cu	*Zn*	*Pb*	*Ni*	*Co*	*Cd*
West Germany	1 200	3 000	1 200	200	NF	30
Denmark	700	6 000	1 200	NF[a]	NF	30
Finland	3 000	5 000	1 200	500	100	30
Sweden	3 000	10 000	300	500	50	15
The Netherlands	600	2 000	500	100	NF	10
France	1 500	3 000	300	100	20	15
Switzerland	1 000	3 000	1 000	200	100	30
Scotland	1 500	2 500	1 500	600	NF	20
Belgium	500	2 000	300	100	20	10

[a] NF, not fixed

exception of Ni. This was probably due to an accidental and rare contamination, since, in Tenerife, there are no contaminating heavy metals industries which discharge wastewater into the sewage station. The essential metals (Fe, Cu, Mn and Zn) are a valuable additional element of sludge which can correct, or offset, certain deficiencies in some of these elements, as was shown by Juste (1979) in trials with maize where Fe deficiencies were corrected by the application of sludge rich in this element.

Compost: domestic refuse–sewage sludge

Table 3 sets out the results of the physico-chemical analysis of the A Teneriffe compost, of the Orotava B compost and of the different and related commercial products analyzed (C, D, E, F, G and H).

The pH which the Tenerife compost shows is almost neutral (7·1), a factor of considerable importance since the assimilation of heavy metals by plants increases as soil pH decreases (Andersson, 1977). Of the commercial products analyzed only products D and F show an acid pH (5·6), but, in the event of an acidification of the soil by a heavy application of either of these two products, it is to be expected that

TABLE 3
Physico-Chemical Characteristics of the Tenerife Compost and Several Commercial Products (Average of Three Repetitions)

		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
	pH (extr. 1:5)	7·1	7·5	7·4	5·6	7·1	5·6	7·4	7·9
	EC (mm hos^{-1} cm) (extr. 1:5)	9·5	2·8	34·5	12·0	6·1	13·5	26·5	8·2
Percent (dry matter)	Volatile Solids	43·6	31·4	28·1	53·0	31·8	59·6	31·5	41·4
	Ash	56·4	68·6	71·9	47·0	68·2	40·4	68·5	58·6
	Total C	25·3	17·1	15·0	30·7	16·7	34·2	13·4	22·5
	Total organic matter	43·6	29·4	25·8	52·8	28·8	59·0	23·1	38·8
	Oxid. C	21·7	11·1	12·6	29·2	15·1	33·9	11·5	16·9
	Oxid organic matter	37·3	19·1	21·7	50·3	26·0	58·4	19·8	29·2
	Total N	2·8	1·3	2·7	2·2	1·7	2·7	1·7	2·2
	C/N	9·0	13·1	5·6	13·9	10·0	12·9	7·9	10·1
	P	1·3	2·1	1·3	0·1	0·1	0·1	1·7	0·7
	K	1·6	1·2	9·2	0·4	0·3	0·2	8·9	1·9
	Ca	5·2	4·8	7·3	0·9	2·3	1·6	16·8	12·9
	Mg	1·1	1·1	0·7	0·7	0·3	0·2	0·6	0·8
ppm (dry matter)	Fe	31 976	35 180	10 031	23 598	28 374	19 995	24 622	74 028
	Cu	193	82	19	51	96	22	398	1 544
	Mn	533	988	116	138	303	92	140	267
	Zn	619	350	54	72	215	50	1 501	5 334
	Pb	386	73	39	38	53	125	24	1 890
	Co	21	20	12	13	17	8	24	75
	Ni	173	54	21	24	29	21	22	26
	Cd	4·8	7	4	1·5	1·7	1·3	11	11

A, Tenerife compost. B, Orotava compost. C, D, E, F, Organic fertilizer or dressings. G, H, Organic mineral fertilizer.

toxicity problems would not appear, since the heavy metals content is relatively low.

The electrical conductivity of all the products analyzed is high, with the exception of the Orotava compost (2·8 mmhos cm^{-1}). The Tenerife compost shows a level of 9·5 mmhos cm^{-1}, rather high but fairly normal in compost obtained from domestic refuse, due mainly to the NaCl content of the original material (Juste, 1980). The products called C and G show high EC values (34·5 and 26·4 mmhos cm^{-1}, respectively) so that their application, even in moderate amounts, could cause a

TABLE 4
Chemical Analysis of Domestic Compost, Sewage Sludge and Manure

Elements	*Compost*[a]		*Sewage Sludge*[b]		*Manure*[c]	
	Interval	*Mean*	*Interval*	*Mean*	*Interval*	*Mean*
N per cent (dry matter)	—	0·96	0·10–17·60	3·90	0·15–1·60	—
P per cent (dry matter)	0·34–0·47	0·40	0·10–14·30	2·50	0·06–0·50	—
K per cent (dry matter)	0·17–0·23	0·20	0·02–2·64	0·40	0·33–0·80	—
Ca per cent (dry matter)	3·72–5·10	4·41	0·10–25·00	4·90	0·35–0·42	—
Mg per cent (dry matter)	0·19–0·25	0·22	0·03–1·97	0·54	0·06–0·12	—
Fe ppm (dry matter)	13 860–20 360	17 110	1 000–153 000	13 000	—	—
Cu ppm (dry matter)	220–490	357	84–10 400	1 210	18–172	37
Mn ppm (dry matter)	750–960	854	18–7 100	380	117–969	270
Zn ppm (dry matter)	1 290–1 760	1 525	101–27 800	2 790	85–566	190
Pb ppm (dry matter)	420–780	599	13–19 700	1 360	1·1–27	5·6
Co ppm (dry matter)	—	—	1–18	5	0·4–9·6	2·0
Ni ppm (dry matter)	170–220	196	2–3 520	320	2·1–24	7·1
Cd ppm (dry matter)	7–10	8·5	3–3 410	110	—	0·28

Data from: [a] Juste (1980). [b] Sommers (1977). [c] Tietjen (1975), Andersson (1977).

progressive salinization and consequent deterioration of soil structure, and serious effects on plants, especially those sensitive to salinity.

The high contents of the total organic matter (43·61%) and oxidizable organic matter (37·34%) of the Tenerife compost, exceeded only by products D and E, make it an important source of humus for island soils very lacking in organic matter, and hence it would produce a series of beneficial effects in the physico-chemical characteristics of agricultural land which, at present, has deteriorated badly. In the case of the Tenerife compost the Volatile Solids and total organic matter values (determined from total C) coincide, which is not true of the other compounds. Some authors analyzing this type of product determine total organic matter by calcination, which is not really exact since, as Brame & Lefevre (1977) point out, there are volatile mineral compounds ($CaCO_3$ and others) which prevent the value obtained by calcination from being considered true organic matter.

The concentration of mineral elements which the compost and the commercial products analyzed (Table 3) show are compared with the data indicated by Juste (1980) for domestic refuse compost, Sommers (1977) for sewage sludge and Tietjen (1976) and Andersson (1977) for manure (Table 4) since the first two products are, at present, in fairly general use as alternative organic dressings to manures (traditional organic matter) in the more developed countries. It is seen that the N, P and K contents of the Tenerife compost are much higher than those shown by compost from domestic refuse, and also from manures, since the latter do not generally exceed 1%. These values are usually higher in the case of sludge, with the exception of K. In the case of Ca and Mg the Tenerife compost concentrations (5·2% and 1·1%, respectively) are higher than those of compost and sludge, and much higher than those of manures. The high Ca levels which characterize composts of urban wastes cause them to be called not only organic dressings but also, sometimes, 'humus-calcium dressings' (Lavoux & Souchon, 1983; Furrer & Gupta, 1983). As regards commercial products, in general the macroelement level is low, with the exception of C and G, but they exhibit a high level of soluble salts as the value of their EC shows (34·5 and 26·5 mmhos cm^{-1}, respectively).

The high macronutrient concentration seen in the Tenerife compost could reduce the large amounts of fast-acting fertilizers which, at present, agriculture needs with ever greater economic and environmental costs. Moreover, its high Ca and Mg content make it suitable for use on island soils which, in general, show a high exchangeable Na content, due mainly to the use of irrigation water rich in sodium (Garcia *et al.*, 1977; Fernández, *et al.*, 1984).

With regard to the micronutrients analyzed (Fe, Cu, Mn and Zn), the Tenerife compost shows levels very much below the limit values for sludge shown in Table 2, with the exception of Fe which is in the same range as that indicated by Clairon *et al.*, (1982). The concentrations found in the literature (Table 4) for compost and sludge are much higher than those obtained in our case, but this does not apply to manures. Some authors (Chaney & Giordano, 1977) note the utility of domestic refuse compost specifically to prevent or correct certain deficiencies in some of these elements due to its relative richness. Thus, the incorporation of the Tenerife compost into agricultural soils could help to offset certain deficiencies noted in wide areas of the island, fundamentally of Zn and Mn (Barroso *et al.*, 1985).

The non-essential heavy metals in our compost (Pb, 386 ppm; Co, 21 ppm; Ni, 173 ppm and Cd 4·8 ppm) are lower than those found in urban refuse compost, and much lower than in the sewage sludge (Table 4), generally not exceeding the maximum limits proposed by several European countries (Table 2). The amounts of Pb and Ni exceed only slightly the more restricted limits. The micronutrient and non-essential heavy metals content of the commercial products is also relatively low, with the exception of product H, which, at present, is widely used in Tenerife as a 'corrector of mineral deficiencies'. This material deserves special mention because of its enormous heavy metals concentration which could cause serious toxicity problems. The dangers of heavy metals toxicity may be immediate or long term, since they may be absorbed by plants, inhibiting their growth, or, migrating through the food chains, cause serious illnesses in animals or man, as well as contamination of underground water on being leached by rainwater (Alexandre, 1979).

As regards the Orotava compost (B), made from plant and domestic residues because of its organic matter content (29·4%), its high and reasonably well balanced macronutrient level and low heavy metals content, it may be considered a good organic fertilizer and its use could be an excellent practice to condition and conserve productive soils in the island.

CONCLUSIONS

From the results obtained we can conclude that sewage sludge, previously sterilized, if used direct from the Tenerife sewage station, could be a very useful product from the agricultural point of view.

The compost obtained from composting of this sludge with the organic fraction of municipal refuse, because of its high content of total and oxidizable organic matter, its high concentration in N, P, K, Ca and Mg, its balanced essential micronutrient content and moderate toxic heavy metals levels, can be considered, in principle, a good, low cost organic fertilizer with possibilities for agricultural use.

In the comparative study between six products on sale, at present, in the island and the compost obtained by us (Tenerife A compost) only two (D and F) show higher organic matter levels, but their nutrient content (P, K, Ca and Mg) and essential oligoelements are noticeably lower than the Tenerife compost. The rest of the products (C, E, G and H) show an obviously inferior agronomic quality, as can be gathered fundamentally from high soluble salts levels (C and G), high toxic heavy metals content (H) and relatively poor organic matter content (E).

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